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Technical Report

Tensile behaviour and strain hardening characteristics of constrained groove pressed nickel sheets

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ABSTRACT

In this study commercially pure nickel sheets are severe plastically deformed at room temperature by constrained groove pressing (CGP) technique and the effect of pass number on the room temperature mechanical behaviour is investigated. Increase in strength observed after first pass is much higher than the increase observed during subsequent passes. Mechanical behaviour of constrained groove pressed sheets indicated negligible strain hardening ability during initial passes; gain in strain hardening ability is observed during latter passes resulting in enhanced ductility. The observation of shortened uniform elongation phase during tensile testing of CGP processed sheets could be linked to the lack of strain hardenability and change in deformation mechanism. Constitutive mechanical behaviour in uniform plastic deformation regime of nickel sheets in annealed condition obeys Hollomon relation whereas severely deformed sheets obey Voce relation closely. Strain hardening characteristics of groove pressed sheets analysed by Kocks–Mecking approach revealed stage-III hardening behaviour associated with high initial hardening rate when compared to annealed sheets. The influence of pass number on dislocation density evolution is assessed by Taylor's expression. The synergistic effect of dislocation generation and recovery on the evolution of constitutive mechanical behaviour in the uniform elongation regime is described by applying single parameter based Kocks model. The kinetics of dislocation storage and dislocation annihilation in severely deformed nickel sheets during deformation corroborated with mechanical properties and dislocation density indicates the dominance of dislocation generation during earlier passes.

1. Introduction

In the recent years much attention has been paid to the development of ultra-fine grained and nanostructured materials due to their superior properties. Several severe plastic deformation (SPD) techniques have emerged in the recent years for producing ultra fine grained materials in bulk metals and alloys [1]. Among the various SPD techniques proposed most of the methods are intended for processing bulk materials; very few methods like accumulative roll bonding (ARB) [2,3], constrained groove pressing (CGP) [4–6], and repetitive corrugation and straightening (RCS) [7–9] are capable of processing sheet materials. The requirement of stringent surface preparation [2,3], the propensity of cracking due to de-lamination of accumulative roll bonded layers [4,10,11] and formation of edge cracks [12] limits the application of ARB processed sheets. Meanwhile in RCS process elongation of sheets causes strain inhomogeneity [11,12]. The recently invented CGP process [4] sans above mentioned problems is considered as promising method for producing fine grained sheet materials for structural applications.

In CGP the sheet material is subjected to repetitive shear deformation under the plane strain conditions by alternately pressing between asymmetrically grooved and flat dies. The CGP die assembly essentially consists of two asymmetric grooved dies for corrugating the sheet and two flat dies for flattening the corrugated sheet. The asymmetric grooved die (Fig. 1) consists of equally spaced groove and the distance between the grooves is maintained as the thickness of the sheet to be processed. The groove angle (θ) is maintained at 45° to obtain maximum uniform shear strain during CGP processing [4]. The entire die assembly is constrained at both ends to ensure plain strain deformation condition. A single pass of CGP involves two stages of alternating corrugation and flattening of sheets. During first stage the sheet is corrugated between asymmetric grooved dies (Fig. 1a and b) imparting shear deformation in the inclined regions followed by flattening between flat dies (Fig. 1c). At the end of first stage total effective plastic strain of 1.16 is introduced in the double hatched regions (Fig. 1c) whereas adjacent white regions in Fig. 1c are left undeformed. Before the start of second stage, the sheet is rotated by 180° along the thickness axis (Fig. 1d) or the asymmetric grooved die is shifted horizontally equivalent to the groove width so that the undeformed flat regions

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